IN THE SPECIFICATION

Please replace the Detailed Description of the Invention with the following:

DETAILED DESCRIPTION OF THE INVENTION

Having summarized various aspects of the present invention, reference will now be made in detail to the description of the invention as illustrated in the drawings and described in the scientific description. While the invention will be described in connection to these drawings and description, there is no attempt to limit the invention to the embodiment or embodiments disclosed herein. On the contrary, the intent is to cover all alternatives, modifications and equivalents included within the spirit and scope of the invention as defined by the appended claims.

Reference is now made to Figure 1 showing the apparatus of the present invention. Cryogenic liquid (10) may be stored in a sump (20), or reservoir, at the bottom gravitational location of the apparatus. The cryogen may be lifted to the entrance of the raceway (24) via one or more augers (22). Alternatively, an impellor-type pump may be used to created vertical flow of cryogen up to the raceway (24). The cryogen may then transition from vertical movement to horizontal flow, and initiate its travel down a sloped raceway (28).

The slope of the raceway can be a factor in the management of cryogen movement in the preferred embodiments for the slope being as follows for the top of the raceway at the product/cryogen interface. The length of the raceway, from the point of introduction of units into the cryogen to the point of units/cryogen separation at the removal mechanism for said units, can be calculated utilizing cryogen flow speed and desired retention time of the units in the cryogen.

The preferred slope can range from about –5 degrees (upward slope) to about + 15 degrees (downward slope) from horizontal. Most preferably the slope is + 5 degrees (downward slope from horizontal). The raceway slope can be produced to be adjustable across a desired range. Beyond the product/cryogen interface the raceway slope is preferred at about +5 to about +15 degrees downward slope with the most preferred at + 7 degrees.

The cryogen with units contained therein can pass though a moving screen conveyor belt (30) that removes the solidified units from the cryogen. The conveyor belt (30) may be made of a screen, a wire mesh, or any suitable porous material that will filter the solidified or frozen units from the cryogen. The cryogen may then return to the sump (20) where it is recycled again.

The pumping capacity of the auger can be in excess of the ability of the cryogen in the sump to keep the entrance full of cryogen. If this operational condition was created, cavitations in the cryogen may occur if the auger is run too fast thereby introducing gas into the auger process. Cavitations in the cryogen may result in the vertical flow not being consistent. Also, an embodiment of the recycling system that consists of two or more augers thereby enables an increased flow without causing the undesirable cavitations and subsequent flow inconsistency.

The cryogen auger (as example of pumping methodology) does not have to be completely vertical however the preferred arrangement for lift is as follows: The auger can be substantially vertical with a plurality of flutes to be machined at about a 14 degree angle from center with a quantity of flute flights of between about 8 and 10 per auger. The flutes preferred spacing is about 2.5 inches apart. The most preferred condition is a substantially vertical auger with a flute angle of 14 degrees from center with a quantity of flute flights of 8 per auger, with a spacing between flutes of 2.5 inches. If it is decided to employ an auger angle other than substantially vertical all flute angles and quantity of flutes thereof can be adjusted accordingly to offset the other than substantially vertical

condition to allow for similar lifting volume of the cryogen. Large numbers of flutes are possible but can result in added vibration.

Reference is now made to Figure 2 in which the flow transition point is depicted. The cryogen may be lifted by the auger to enter the raceway (24). Motion of the auger (22) may create a circular and vertical direction (34) of the cryogen. Upon exiting the recycling system at the top of the auger, the direction of the fluid body movement is vertical and circular. The flow may change to a fundamentally horizontal flow. The transition from vertical to horizontal flow may result in the production of back eddies and reverse currents (36). Back eddies and reverse currents (36) can result in a spring bubbling-effect up into a body of cryogen then flowing in a horizontal direction.

These back eddies and reverse currents can be allowed to settle out as the fluid converts to basically horizontal flow (38) in advance of the introduction point (42) of the small volumes of a desired substance, such as liquid, semi-liquid, semisolid or solid. Upon introduction into the cryogen, these small volumes may be referred to as units. In another embodiment, a control means (40) may be introduced at the flow transition point to decrease the intensity of the back eddies and reverse currents. The control means may be a barrier, screen (25), baffle (21) or dam (23). In a further embodiment, the apparatus may be adapted to inject a time delay for flow transition. In this embodiment, the auger may rotate with slower speed, there may be a dam before the introduction zone, or a diffusion pool may be added after the introduction zone.

The length of the raceway can determine the retention time of the units as a function of desired exiting temperature or required time necessary to ensure solidification in the cryogen given a particular speed of motion. In some cases the depth or speed of the cryogen can be adjusted to adjust retention time. In such cases a baffle, screen or a dam is placed in the raceway after the introduction point. A dam obviously increases the depth of the cryogen. A baffle aids in the direction of flow of the cryogen and units. A screen aids in the control of the internal currents in the cryogen.

The recycling of the cryogen can maintain a constant circular flow as it travels down the raceway back to the sump and up again to the entrance to the raceway (24).

The small volumes of substance can be introduced to the cryogen flow via a series of introduction nozzles (44) that introduce the liquid by streaming, or as individual droplets, either by gravity feed or under pressure. Droplets (46) can be predefined in volume by a specialized pump or can be determined by the particular surface tension of the liquid and form a droplet that can be released like a drip from a dripping tap.

The number of nozzles utilized for the introduction of small volumes of liquid, are a function of the engineering of the total unit. Preferably, multiple nozzles may be utilized. The actual number of nozzles utilized is a function of the total volume of liquid that the system can sustain while still maintaining the desired results. In general, the faster the speed of individual units being introduced, the faster the lateral movement of the cryogen required in order to achieve the results desired. In addition to pure cryogen velocity the higher the number of individual units being introduced the greater the surface area of the introduction point required.

The introduction point (42) may be positioned downstream from the introduction of the recycled cryogen such that eddies and back currents may have time to settle and a consistent forward flow is achieved. However, the introduction point (42) may be the same position as the entrance point (35). The distance from the recycled cryogen entrance (35) to the introduction point (42) can be dependent upon the maximum flow capacity desired for the equipment. An example of a desired result at the introduction point is a reasonably smooth surface on the flowing cryogen.

Preferably, the distance between the nozzles (48) is sufficiently distant such that the droplets or steams will not combine with each other before hitting the surface of the cryogen. Combination of droplets may also be a function of the height of the nozzles above the cryogen surface. Also, the nature of the product being processed can influence the combination of the droplets. The distance between nozzles, height above cryogen

surface and nature of product being processed are variable and may be adjusted by user-designation.

When a droplet is introduced into a horizontally moving body of cryogen, the resulting unit may be moved away from the introduction point (42). The faster droplets are introduced, the faster the flow of cryogen that is required to move the unit (50) out of the way of the next introduced unit. Preferably, the unit is transported immediately from the introduction zone by the horizontal cryogen flow, thereby reducing the interaction between droplets and unformed units. The speed of the process may be controlled partly by the volume of cryogen recycled, the speed of the recycling of the cryogen, and the slope of the raceway.

Another management tool is the distance that the droplet will pass through before coming into contact with the LN2. The distance of the droplet height or individual liquid unit height from the body of LN2 can be dependent upon the liquid product to be frozen and could range from very low to very high. The preferred variance is from about 4 inches to about 36 inches above the cryogen. Depending on the product makeup (i.e. solid contents, viscosity and surface tension) and the desired results one wishes to achieve (i.e. consistent shaped pellets of varying degrees or misshapen and agglomerated pellets (i.e. Popcorn shaped) or many other combinations including frozen splatter) the height variance can be substantial. Also, liquid product pumping capacity may require establishment as to not overburden the system with too much liquid to be frozen and hence compromise the results desired or efficiencies of a certain type and size of unit/equipment. Testing of these parameters can be established to correlate to the needs of a particular end user and hence management for said requirements can be forecasted and built in to satisfying the existing and future needs of a user.

The distance of drop or droplet combined with its size and mass will to an extent demand that a particular depth and speed of LN2 be available in order to inhibit the droplet from hitting the actual bottom of the raceway in advance of the droplet forming its initial crust.

This methodology results in the gasification created by a particular unit not being added to the gasification of the next unit. In addition, increased flow may prevent the physical interaction of units while they are very susceptible to physical damage, as they are remote from each other.

The violent gasification results in cavitations. Cavitations (54) are individual bubbles that eventually break the surface of the cryogen. In effect the surface becomes covered with cavitations, which present a jagged surface to which the droplets contact. However, these cavitations can be remarkably destructive to droplets when they are introduced into the flow of cryogen. Maintenance of a smooth cryogen surface at the introduction area can be one of the essential parameters in managing the form and structure of the resultant units. This may be accomplished by maintaining a steady horizontal flow of cryogen (56).

As the heat is transferred from the units to the body of cryogen, the currents may move the actual cryogen molecules that are in the process of going through a change of phase or vaporization. Since the actual molecules that are absorbing heat are continually being moved away from the solidifying unit much of the gasification that would normally occur at the interface may be delayed or occur at a point away from the interface.

The internal currents, still active due to the recycling systems' motion, assist in the dispersion of the gas and heat from the interface. The gasification that occurs within the body of the cryogen can create additional currents that assist in the dispersion of subsequent gasification and heat. The movement of the gas bubbles through the fluid body of the cryogen enhances the existing currents and creates new ones. These currents can aid in the desired effect created by the currents. This can minimize physical damage as a result of the violent gasification. The movement of the gasification and heat away from the interface minimizes the normal encapsulation of the forming unit by the gasification. When a unit is encapsulated in gasification the speed of heat transfer is inhibited, as the gas does not absorb heat as quickly as the liquid cryogen absorbs heat.

The result of minimizing encapsulation is that physical contact with the liquid cryogen is maximized, thereby maximizing heat transfer.

The newly forming units are physically moved out of the way of the next introduction of units as a result of this controlled lateral flow of cryogen, thereby minimizing the physical interaction of forming and formed units with each other. The continued flow down the sloped raceway can maintain this distance between the units. This may assist in controlling the agglomeration that would be expected to occur, as well as the physical interaction and resulting deformation or structural damage to the units that would result.

Depending upon the product and the management desired in general it is preferred that the cryogen flow be such that product is moved away from subsequent newly introduced product. However for some products minimal or substantial no flow of the cryogen may be advantageous. This is because even without any river type flow of the cryogen there is substantial currents and resulting movement thereof caused within the body of the cryogen as a result of the significant gasification that occurs at the interface between the introduced product and the cryogen. This substantial movement is over and above the great deal of movement that already occurs from the steady state gasification that occurs even without the introduction of the substance to be frozen.

The preferred rate of cryogen flow is relative to the individual liquid units to be frozen however for each product there can be established of a most preferred rate. This is ultimately accomplished through the testing of each individual liquid type product to be frozen and adjusting the parameter for cryogen flow accordingly to establish a most preferred rate. As well the amount of pumping capacity can vary with the size of each piece of equipment constructed and the number of pumping sources available. For some of what may be considered larger sized pieces of equipment produced (this is of course somewhat subjective to individual industry definition of larger scale) a preferred range for cryogen pumping capacity for example would be about 100 to about 150 liters of cryogen per minute into a river width of about 8 to 12 inches. A most preferred rate would be 120 liters per minute of pumping capacity with a river width of 10 inches. It is

important to note that this technology is scaleable (small and large). For comparative purposes for smaller sized equipment than that as cited above the above ranges could be about 50% of those values (once again dependent upon industry definition and need). The cryogen depth can be managed to be within a preferred rate of from about 1 inch to about 3 inches deep by adjusting the cryogen flow rate and/or the horizontal slope of the tray and/or by introducing a downstream flood gate/dam or a narrowing of the raceway that will allow more or less cryogen to flow over it past its point of location depending upon the cryogen depth desired.

For example, a product of composition such as skim milk dropping simultaneously from approximately 48 nozzles from a height of between 20 and 25 inches into a flowing cryogen source moving along a 10" trough at a + 5 degree angle at the point of interface and then descending at a rate of approximately 2.5 feet per second for a time of approximately 20 seconds (residence time) will produce a consistent size and shape of pellet in a quantity of approximately 325 to 375 pounds per hour.

In specialized product situations, individual channels can be built in the raceway such that each nozzle utilized at the introduction point directs the droplets to follow a particular channel thereby stopping any horizontal interaction between units that were introduced at the same time.

When the gasification is removed remotely from the interface and mixed into the general body of the cryogen, the gasification can create additional random mini-currents within the body of the cryogen that assist in the general manipulation of the inherent currents and their subsequent effect as well as encouraging continued movement of the gasification.

This movement of the gasification away from the interface inhibits the initial floatation or levitation of droplets caused by the violent gasification (52), thereby minimizing the interaction of floating units that are randomly thrown around and have the possibility of hitting the sides of the raceway and/or each other.

The form of the raceway can also assist in this management and manipulation. A spiral raceway can continually change the direction of the flow of the cryogen thereby not allowing it to stabilize in a particular direction. A cascading raceway may cause the cryogen to cascade thereby enhancing internal currents and thereby fortifying random currents and flow. A linear raceway may allow the flow to stabilize.

The solidified units may be removed from the flow of cryogen via a conveyor belt screen with spacing in the screen such that the cryogen flows through the belt while the formed units do not flow through the belt. The belt may take the formed units to the exterior of the equipment where they are stored or utilized as desired. The exit of the cryogen gas due to evaporation or gasification from the equipment can be where the conveyor belt removes the solidified units. Therefore, the units after removal from the cryogen may be in an atmosphere of very cold gas. By adjusting the speed of the belt, the time that the units are exposed to this cold gas can be determined. There may be additional cooling of the units from this exposure to the expelled gas.